D0 Note 4692

Impedance Matching and Frequency Analysis of the BLS Trigger and Pleated Foil Cables for the Run IIb L1 Calorimeter Trigger Upgrade

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Abstract

For the Run IIb upgrade of the L1 calorimeter trigger, a transition system will be used to transport the signals from the existing trigger cables to the new electronics. The transition system is composed of passive electronics cards and cables. For this note, the impedance mismatch between the existing trigger cables and the transition system has been measured to be 7 Ohms. The frequency response of the transition system has also been analyzed. By introducing a 7 Ohm resistance to match the impedance between the the existing trigger cable and the cable of the transition system, the fraction of the signal leaving the transition system with respect to the output of the trigger cable is about 90% at the frequencies of interest (1-3 MHz).

I. Introduction

As part of the Run IIb upgrade [1], the calorimeter trigger electronics on the first floor of the moveable counting house (MCH) will be replaced, while the trigger cables[1] will be reused. However, the existing trigger cables cannot be plugged directly into the new electronics, so a transition system has been designed. More details on the cabling and the transition system can be found in D0 Note 4430 [2]. The mechanical issues were studied and reported in D0 Note 4651 [3].

The transition system is composed of passive electronics cards and cables which transmits the signals from the trigger cables and to the backplane of the Analog-to-Digital Filter (ADF) crates [4].

- Patch panel cards [5]
    - Inputs from the trigger cables (16 per patch panel card)
    - Outputs to the pleated foil cables (2 per patch panel card)
- Pleated foil cables, series 90211, manufactured by 3M [6]. The unbalanced characteristic impedance specification is 72 Ohms. The length of the final production of the pleated foil cables will be ten feet (3.05 m), however the prototype cable used in these tests was nine feet and two inches (2.79 m) in length.
- Paddle cards [5]
    - Inputs from the pleated foil cables (2 per paddle card)
    - Outputs to the ADF backplane (1 per ADF card)

This note reports on the electrical issues of the transition system, in particular the impedance mismatch between the existing trigger cables and the pleated foil cables, and the frequency response of the transition system in the range of 1-20 MHz. Two important questions need answering. With which resistance to ground should each analog input line be terminated on the ADF card? What fraction of the signal amplitude is lost in the transition system?

II. Impedance Matching

The existing trigger cables were installed at the very beginning of Run I [7]. There were two types of trigger cables used to run from the BLS cards in the platform to the L1 Cal trigger electronics in MCH1 [4]. One of them was made by a company called ASTRO, and the other by a company called New England Wire. Most of the trigger cables have a blue-colored shielding, but some of the high eta cables have a gray-colored shielding. The Zo of these two types are different: one is 80 Ohms and the other is 78 Ohms. For the Run I and Run IIa circuits, the terminators for the BLS trigger pick-off signals were designed for 79 Ohms.

The trigger cables are made of 0.1" diameter ribbon coaxial cable with 16 coaxials per ribbon. Four adjacent coaxial cables carry the differential electromagnetic (EM) and

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[1] Trigger cables are also referred to as baseline subtractor (BLS) cables as they originate from the calorimeter BLS racks inside the detector platform and run to the MCH racks 103-112.

hadronic (HD) signals for one Trigger Tower (TT). The lengths are: 130 feet to the north end calorimeter (ECN), 150 feet to the central calorimeter (CC), and 180 feet to the south end calorimeter (ECS). There are no problems with crosstalk or reflection. Although there is no apparent noise due to the long cables runs from the platform to MCH1, there is a 7 to 15% signal loss at the frequencies of interest of 1-3 MHz (Table I).

Table I. Trigger cable signal attentuation and signal loss as a function of frequency. The signal loss is 7 to 15% at the frequencies of interest (1-3 MHz).

MHz	dB loss per 100 ft	Voltage Ratio
1	0.60	1.072
2	0.80	1.096
4	1.25	1.15
6	1.48	1.19
8	1.72	1.22
10	1.92	1.25

The pleated foil shielded cables manufactured by 3M were recommended because of their low skew for an accurate high-speed data transfer. Series 90211 has the nearest characteristic impedance specifications (unbalanced = ground-shield-ground) to the existing trigger cables.

The characteristic impedance (Zo) for the 90211 cable assembly was measured by a 3M engineer[2] in two ways: a) an inductance, capacitance and resistance (LCR) meter and b) a time domain relectrometer (TDR). The average Zo value with the LCR meter was 73.1 Ohms. The average Zo from the TDR data was 73.3 Ohms, with the shield grounded, while the average Zo with the shield floating was 74.2 Ohms. The average value of Zo for the cable, looking at both methods, appears to be very close for a grounded shield, 73.1 Ohms for the LCR meter versus 73.3 Ohms for the TDR, well within the ± 10% tolerance range. All data supporting this test can be found in Figure 1.

A resistor in series can be added to the signal path on the patch panel card in order to match the impedance between the trigger cable and the pleated foil cable. A spare working 150 foot trigger cable was used in the tests with an assumption that the impedance was 80 Ohms. The trigger cable was connected to the transition system (patch panel card, pleated foil cable and paddle card). A signal was sent along one channel of the trigger cable with a pulse generator [8] and read out with an oscilloscope [9] at three different places along the signal path (Figure 2). Variable resistors were added to terminate the signal properly at R1 and R3 (108 and 73 Ohms respectively). A 7 Ohm resistor was placed at R2 to match the characteristic impedances between the trigger cable and the pleated foil cable

[2] Frank J. Cuzze (fcuzze@mmm.com) from the 3M office in Austin, TX in Nov 2004, sent via email the data he measured for the characteristic impedance of the 90211 cable assembly.

Sample 1 1 MHz

Balanced	Impedance (Ohms)	Prop. Delay(ns/ft)	Unit Cap.(pF/ft) @ 1 MHz	Inductance (uH/ft)	Velocity of Propagation (%)
Minimum	133.52	1.50	11.08	0.20	66.45
Maximum	135.77	1.53	11.45	0.21	67.56
Range	2.247	0.025	0.371	0.004	1.118
StdDev	0.6187	0.0067	0.0815	0.0011	0.2969
Average	134.73	1.52	11.28	0.20	66.83

Sample 1 1 MHz

Unbalanced	Impedance (Ohms)	Prop. Delay(ns/ft)	Unit Cap.(pF/ft) @ 1 MHz	Inductance (uH/ft)	Velocity of Propagation (%)
Minimum	71.85	1.50	20.21	0.11	66.34
Maximum	74.41	1.53	21.26	0.11	67.56
Range	2.561	0.028	1.050	0.002	1.219
StdDev	0.5808	0.0064	0.2443	0.0005	0.2838
Average	72.85	1.52	20.88	0.11	66.80

Figure 1. TDR data from measuring the impedance of a ten foot pleated foil cable.

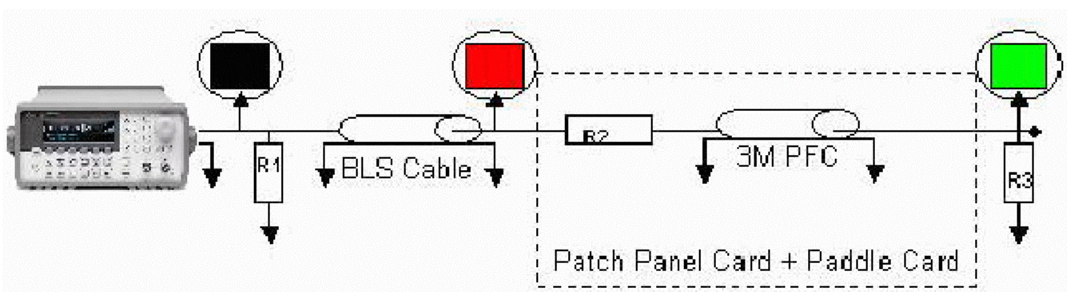

Figure 2. Signal test setup. The trigger cable was connected to the components of the transition system: patch panel card, pleated foil cable and paddle card. A signal was sent along one channel of the trigger cable with a pulse generator and read out with an oscilloscope at three different places along the signal path.

The pulse generator was set to provide a signal with a 2 μs duration, 700 mV amplitude and 50 ns rise time (Fig. 3a). For a sanity check, the signal from the pulse generator was plugged directly into the oscilloscope (Fig. 3b) to make sure a clean signal was being provided by the pulse generator, and that the oscilloscope agreed with the pulse generator setting.

At three places along the signal path, the signal was directed to the oscilloscope: the input to the trigger cable, the output of the trigger cable and the output of the transition system (paddle card). The shapes and amplitudes of the three signal pick-offs are shown in the oscilloscope display in Figure 4. The amplitudes are 692 mV (black line), 598 mV (pink line) and 538 mV (green line) respectively. The DC fraction of the signal leaving the transition system relative to the output of the trigger cable is 90.0 ± 1.5%. The output signal of the transition system (green line) follows the shape of the output signal of the trigger cable (pink line); the features in the signal shapes are not associated with the transition system.

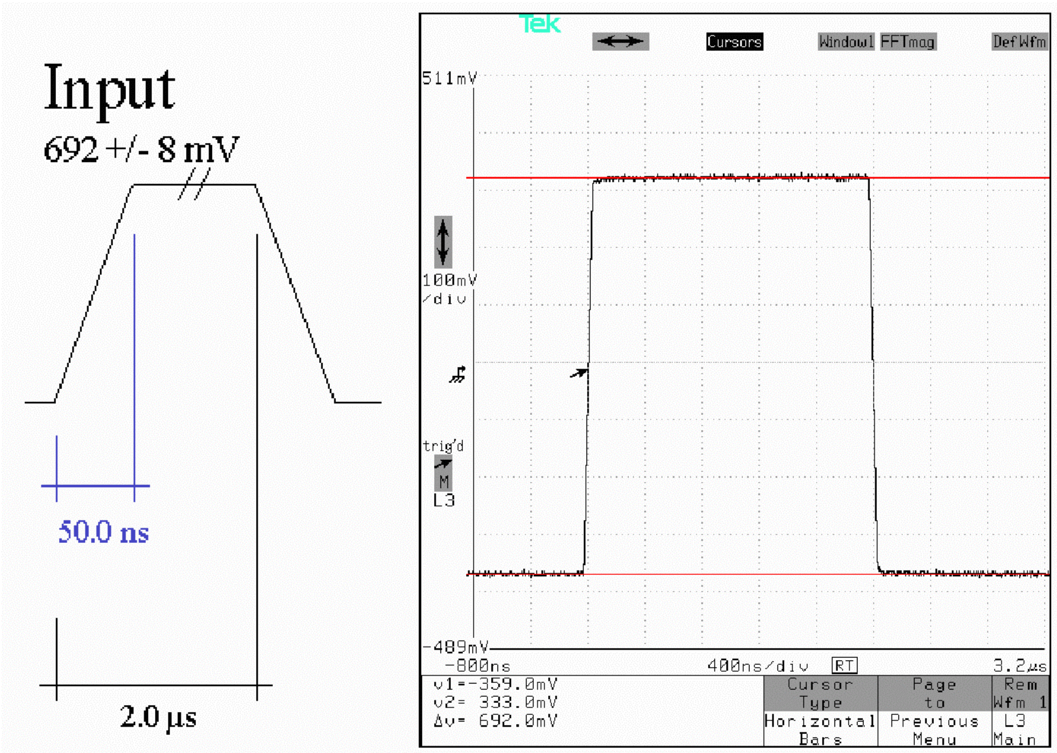

Figure 3. a) Pulse generator baseline signal specifics and b) baseline signal as seen on the oscilloscope.

The slow turn on of the signal in the trigger cable (Fig. 4) is due to the attenuation of the higher frequency components of the square wave, and is not considered a problem. This is the best that can be done without introducing active amplification to recover the higher frequencies. The higher frequencies beyond 10 MHz are not important to the trigger signal.

Studies were performed by varying the R2 resistor (Fig. 2) from 0 to 16 Ohms while keeping R1 and R3 constant. The shape of the output signal from the transition system was stable over this range, while as expected the signal fraction decreased with increasing impedance. Additional work was done to understand the signal termination at R1 and R3. Those efforts were logged in reverse chronological order on a private web page [10].

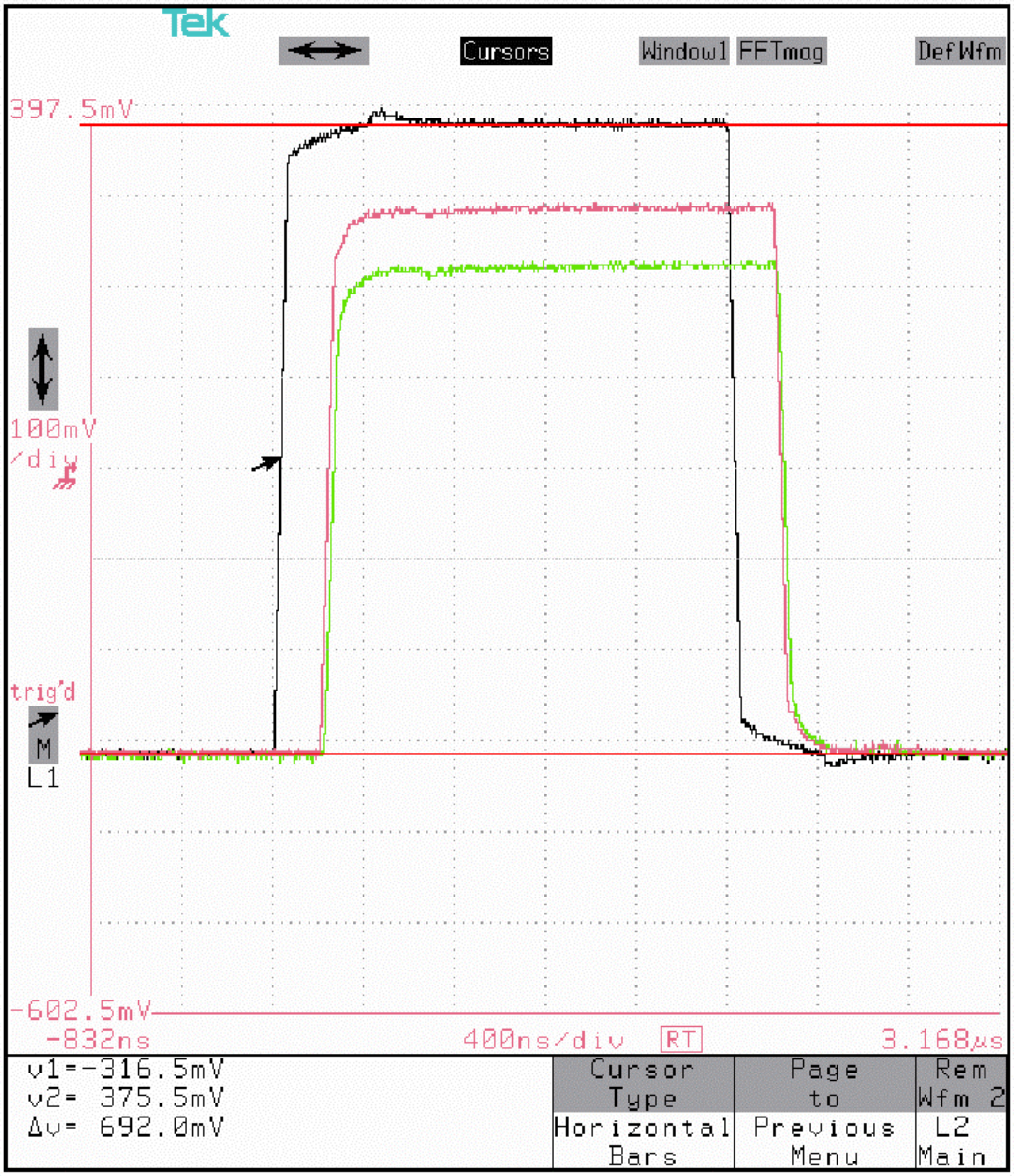

Figure 4: Oscilloscope display of the signal at the input of the trigger cable (black line), the output of the trigger cable (pink line) and the output of the transition system (green line). A 7 Ohm resistor was used to match the impedance between the trigger and pleated foil cables, such that 90% of the input trigger signal makes is through the transition system.

III. Frequency Analysis

The principal Fourier components in the BLS trigger pick-off signals from real energy deposits in the calorimeter are in the 1 to 3 MHz range[3]. Oscilloscope images of BLS trigger pick-off signals are on the web [11]. Most of the signal on the trigger cables above 10 MHz or so is just noise. The ADF-2 card makes two high frequency RC cuts on the analog signals starting at about 15 MHz before the signals are digitized.

The percentage loss of the signal as it transmits through the transition system effects the ADF-2 design, in particular the setting of the full scale input range of the ADF-2 cards. In any one of the 3 "GeV of E to BLS signal Volts" calibration ranges, there is a 3:1 ratio of sin theta [4]. The converters on the ADF-2 are 10-bit, with 8-bit numbers coming out, leaving - only 4:1 with which to play. The 3:1 ratio of input signals must be correctly centered in this 4:1 dynamic range, so the signal loss through the cable transition system needs to be taken into account. The signal levels are known at the couple of percent level or better from the calibration of the current L1 calorimeter trigger.

Using the same pulse generator, the input signal was changed to a 700 mV sinusoidal pulse and varied from 1 MHz to 20 MHz. The same configuration as Fig. 2 was used with R1, R2 and R3 equal to 108, 7 and 73 Ohms respectively. The fraction of the signal coming out of the transition system with respect to the output of the trigger cable is illustrated in Figure 5 over the range of 1-20 MHz. The ratio falls from ~90% at 1 MHz to ~80% at 10 MHz.

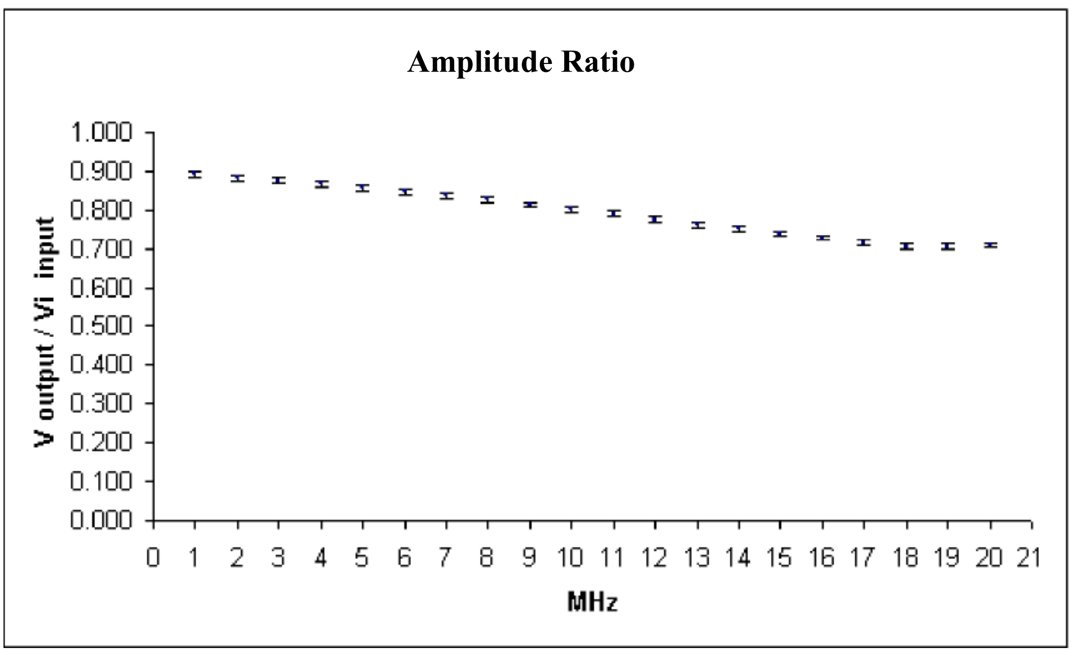

Figure 5. Amplitude ratio of the ouput to input signal of the transition system as a function of frequency.

[3] From an email disussion with Dan Edmunds, Nov 2004.

In Figure 6, the attenuation is shown over the same range, increasing from 1 dB at 1 Mhz to 2 dB at 10 MHz. Figure 7 shows the phase between the input and output signals of the transition system. The delay is nearly flat at ~20 ns. Figure 8 shows the signal amplitudes as a function of the signal frequency for the trigger cable input, trigger cable output and the transition system output.

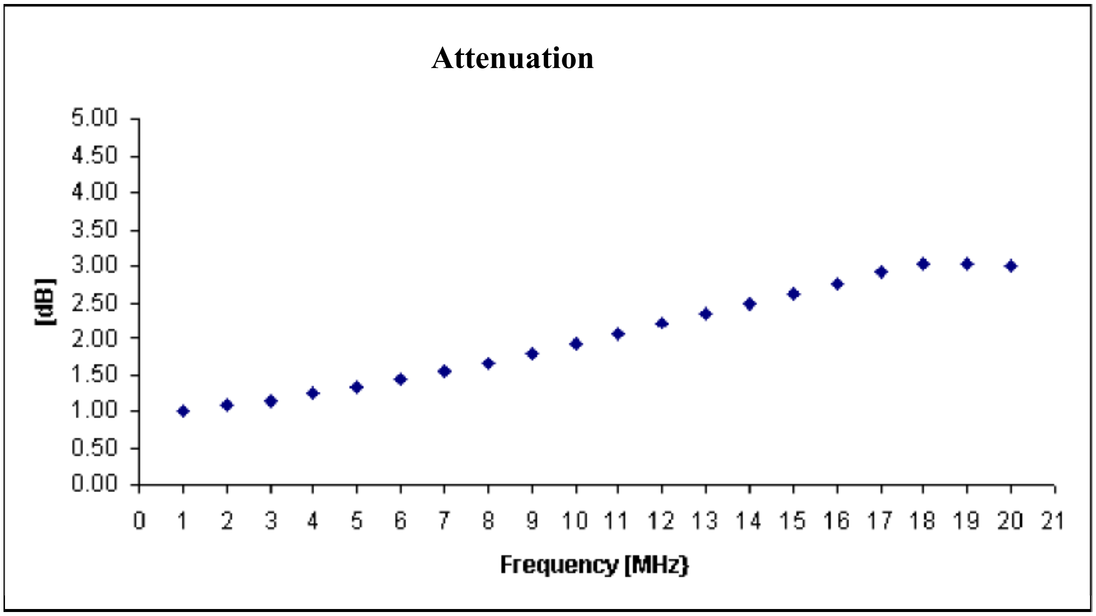

Figure 6. Attenuation of the signal through the transition system as a function of frequency.

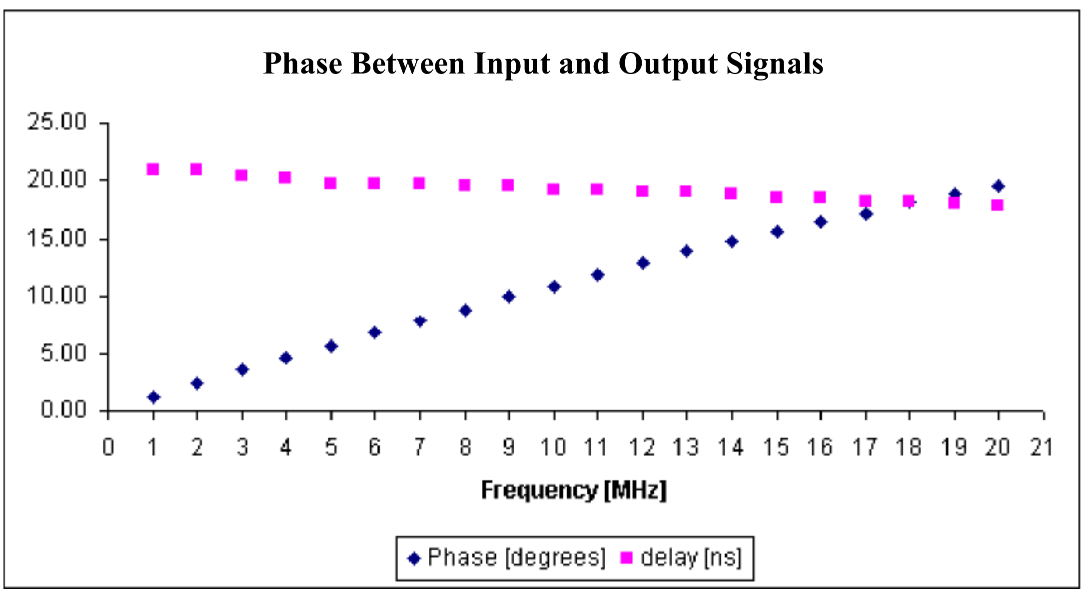

Figure 7. Phase between the input and output signals of the transition system as a function of frequency.

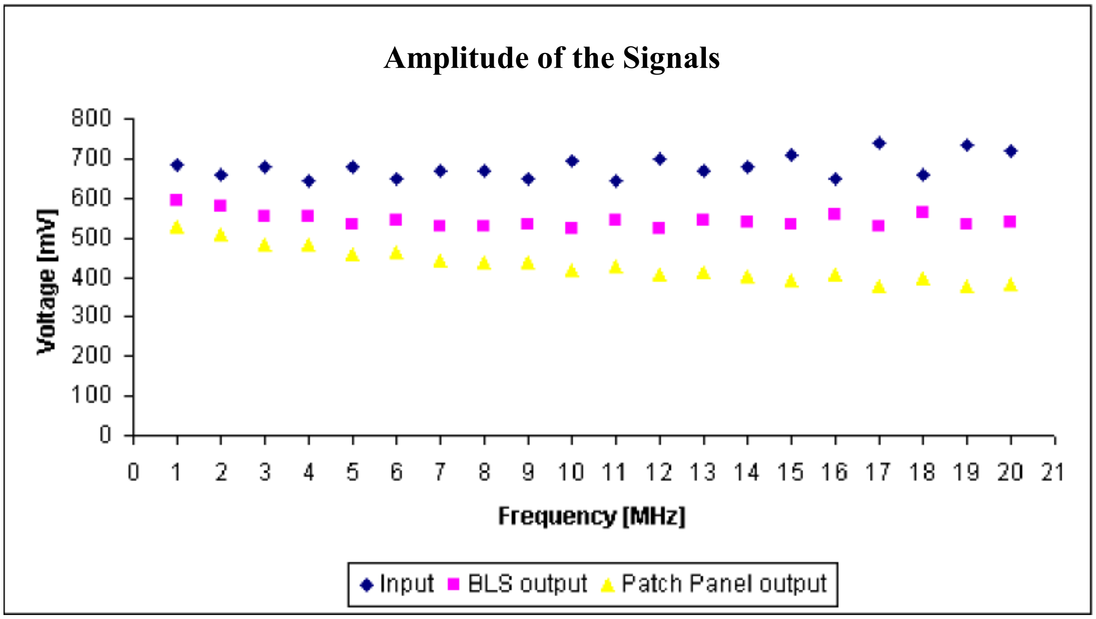

Figure 8. Signal amplitudes as a function of the signal frequency. Shown is the input of the trigger cable (diamonds), the output of the trigger cable (squares) and the output of the transition system (triangles).

VI. Conclusions

The signal transmission along the BLS and pleated foil cables of the trigger input to the ADF system has been studied. For an optimum impedance match, the termination of each pleated foil cable line at the ADF should be 73 Ohms. In addition, 7 Ohm resistance should be added in series to each input line from the BLS cable on the patch panel card.[4]

Introducing a 7 Ohm resistance to match the BLS impedance with the pleated foil cable, the fraction of the signal coming out of the transition system with respect to the output of the BLS cables falls from 90% at 1 MHz to 80% at 10 MHz. In the region of primary interest, 1-3 MHz, the average signal loss is ~10%.

[4] The 7 Ohm resistors are jumpers applied on the patch panel cards and can be adjusted if needed.

V. References

[1] "D0 Run IIb Upgrade Technical Design Report".
D0 Collaboration, FERMILAB-PUB-02-327-E, Dec 2002.

[2] M. Camuyrano et al., "BLS-to-ADF Transition System for the Run IIb L1 Calorimeter Trigger Upgrade", D0 Note 4430, March 2005.

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[4] D. Edmunds et al., D0 Run IIb Level 1 Calorimeter Trigger, ADF Sub-System.
URL www.pa.msu.edu/hep/d0/run2b/index.html

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URL cp.literature.agilent.com/litweb/pdf/5968-8807EN.pdf

[9] Tektronix Digitizing Signal Analyzer DSA 602A.
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[10] M. Camuyrano. D0 Run IIb L1 Calorimeter Trigger, Signal Testing.
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[11] D. Edmunds et al., D0 Run IIa Level 1 Calorimeter Trigger, Trigger Pick-Off.
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